§27. Evaluation of Particle Source Rate and its Influence on Particle Transport

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The hydrogen Balmer-α line profile is measured for plasmas having different magnetic configurations. Line emissions of neutral hydrogen dominantly take place as the atoms penetrate into confined region from outside. The line profile is found not to be approximated with a single Gaussian profile or, more precisely, it has rather broad tail components. Since the possible broadening mechanism is the only Doppler broadening under the present plasma condition, the line profile is understood as a superposition of different temperature components.

We have carried out numerical inversion of the Laplace transform for the observed line profile, and have derived the intensity distribution function against the atom temperature [1]. The temperature dependence is interpreted to the spatial dependence with the help of other diagnostic data so that the radial profile of photon emission rate is derived. The photon emission rate then yields the ionization rate as a result of the collisional-radiative model calculation.

The ionization rate or the particle production rate in the confined region is an important parameter to evaluate the particle confinement time, which is a measure of the confinement performance of plasma. The particle confinement time of electrons or protons inside a magnetic surface ρ , $\tau_{\rm p}(\rho)$, is defined as

$$\tau_{\rm p}(\rho) = \frac{\int^{\rho} n_{\rm e}(\boldsymbol{r})\,{\rm d}V}{\oint^{\rho} \boldsymbol{\Gamma}(\boldsymbol{r})\cdot{\rm d}\boldsymbol{\sigma}} = \frac{\int^{\rho} n_{\rm e}(\boldsymbol{r})\,{\rm d}V}{\int^{\rho} \boldsymbol{\nabla}\cdot\boldsymbol{\Gamma}(\boldsymbol{r})\,{\rm d}V} \qquad (1)$$

where $n_{\rm e}(\boldsymbol{r})$ and $\Gamma(\boldsymbol{r})$ are the electron density and the outward flux of electrons at position $\boldsymbol{r}$, respectively, $\int^{\rho}\cdots\,{\rm d}V$ means the volume integral inside the surface ρ, and $\oint^{\rho}\boldsymbol{\Gamma}\cdot{\rm d}\boldsymbol{\sigma}$ is the surface integral of $\boldsymbol{\Gamma}$ over the surface ρ. With the help of continuity equation, i.e.,

$$\frac{\partial n_{\rm e}(\boldsymbol{r})}{\partial t} + \boldsymbol{\nabla}\cdot\boldsymbol{\Gamma}(\boldsymbol{r}) = S(\boldsymbol{r}), \qquad (2)$$

where $S(\boldsymbol{r})$ is the ionization rate of hydrogen atom, Eq. (1) is rewritten as

$$\tau_{\rm p}(\rho) = \frac{\int^{\rho} n_{\rm e}(\boldsymbol{r})\,{\rm d}V}{\int^{\rho} S(\boldsymbol{r})\,{\rm d}V - \int^{\rho}\frac{\partial n_{\rm e}(\boldsymbol{r})}{\partial t}\,{\rm d}V}. \qquad (3)$$

We have made analysis for two different types of discharges: One is a discharge with $R_{\rm ax} = 3.6\,{\rm m}$ and $B_{\rm ax} = 2.75\,{\rm T}$, where $R_{\rm ax}$ and $B_{\rm ax}$ are the major magnetic axis radius and the magnetic field strength at the magnetic axis, respectively. The aim of the experiment is getting high stored energy with gas puffing. The other is a discharge with $R_{\rm ax} = 3.59\,{\rm m}$ and $B_{\rm ax} = 0.41\,{\rm T}$ aiming at obtaining the highest β, which is the plasma pressure normalized to the magnetic pressure. The apparent difference between the two discharges is the magnetic field strength.

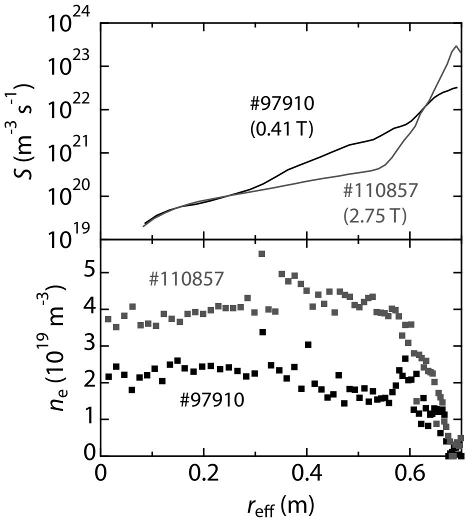

Fig. 1: Profiles of the ionization rate S and $n_{\rm e}$ as a function of $r_{\rm eff}$ for the two discharges.

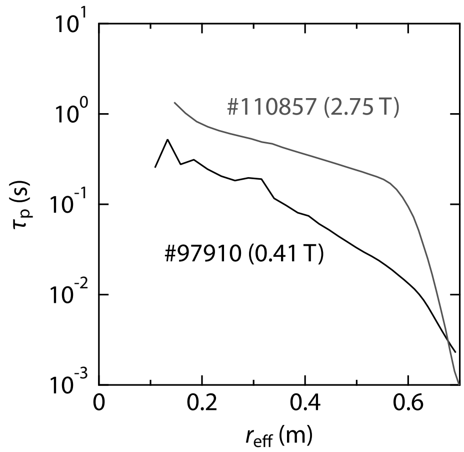

Fig. 2: Particle confinement time $\tau_{\rm p}$ as a function of $r_{\rm eff}$ for the two discharges.

Figure 1 shows the ionization rate profiles in the stationary phase of the two discharges, where the horizontal axis indicates the average minor radius $r_{\rm eff}$. The decay of S as going deep into the core region is much faster in the high field case than in the low field case. This may be due to the higher electron density in the former case.

From the results in Fig. 1, we have evaluated τ_p as a function of $r_{\rm eff}$. The results are shown in Fig. 2. In the high field case, a turning point is clearly seen at around $r_{\rm reff} = 0.6\,{\rm m}$, which approximately corresponds to the position of the last closed magnetic flux surface. In the low field case, no such clear boundary is seen. In the present low field case β is so high that the magnetic surface may be perturbed and broken in the plasma edge region. This effect could be observed in the $\tau_{\rm p}$ profile. The absolute value of the confinement time is approximately one order smaller in the low field case than in the high field case.

1) Goto, M. et al.: Nucl. Fusion **51**, 023005 (2011).